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COGNITIVE DISPOSITIONAL EMPATHY ON MATHEMATICAL ENGAGEMENT AND PERFORMANCE

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Abstract:

The study used a cross-sectional quantitative survey design to study the influence of Dispositional Empathy on Mathematical Engagement (mathematical performance) among Techiman North Senior High School (SHS) students in Ghana, West Africa. Participants across SHS 1, 2 and 3 were selected from the three SHS to take part in the study. The methodology used for the study was the descriptive research design professed to investigate the research questions along the scale of qualitative analyses using the Pearson independent chi-square test statistics. The study's inferential statistics was done under the assumption of the qualitative test using chi-square estimator supported with Cramer's V and under rare cases, the use of simple percentages. This helped in analyzing the existing collinearity among the study variables and defining a best fitted hypothetical test for the study variables considered to be associated. It was concluded however that, dispositional empathy on student Academic Performance (AP) is independent of students' response on cognition in mathematical engagement. Again, the fact that a student see mathematics as difficult to understand cognitively or not doesn't mean he or she can't pass mathematics evaluated lesson. That is, a student noticing mathematics as intuitively difficult or easy doesn't guarantee passing with excellent, very good, good, credit, pass or fail etc. After careful analyses of the study variables, we recommend that teachers should try as much as possible to satisfy students' affective domain when considering lesson objectives, methodology and evaluation of mathematical lessons. Students should take their mathematics lessons serious and must have positive cognition with confidence in Mathematical lesson.

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1. Introduction

In delivering mathematics, there are several major factors for which mathematics educator could focus to bring about achievable mathematical engagement and understanding of mathematical concepts. Content delivery should be appealed to the head more since it involves more reasoning and calculations. The knowledge-based acquisition restrictions of the content and engagement could be measured along gender dispositional empathies. Issues of emotions should not be a major concern in adolescent's stage in human developmental stages. It is therefore imperative that mathematics teachers recognize these gender dispositions which cause difficulties in mathematical engagement and understanding.

Empathy is an individual's ability to experience the perspectives and feelings of other people's experience or what they are going through (Davis, 1994). The dispositional component means that, the ability to do so is something that is internal and not learnt and can be genetically bounded. In other words, dispositional empathy is the inherent ability to sense or feel what others are going through in such a way that it produces a willingness or desire to intervene and help (Decety and Lamm, (2006). Davis (1994) states that research on dispositional empathy started with emergence of two main perspectives. One perspective viewed dispositional empathy as affective in nature and the other viewed it as cognitive in nature. Therefore, earlier researchers made distinctions between cognitive empathy and affective sympathy. Researchers therefore took an "either or" approach towards an assessment of how cognitive and affective components interact to produce dispositional empathy. The current study therefore adopted the integrative approach to study mathematics engagement by assessing gender component of the dispositions with respect to students' mathematical engagement of Atiwa Senior High School (SHS) students in Ghana comprising the three principal SHS.

The senior high school of the educational system in Ghana is a crucial one because it is at this level that some specialization begins. It is from this level that specialized training colleges and tertiary institutions admit their students. However, this level of Ghana's educational system is hit with problems that is geared towards students' inability to appreciate mathematics and get along with it well. Salient among the root causes of this phenomena is the gender dispositional empathy viewed as either male or female perform better in mathematics, or perhaps, engage along well with the other respectively. This is why it has become necessary for researchers to be interested in looking at this psychological syndrome to investigate how this gender dispositional empathy influence mathematics engagement at Atiwa Senior High Schools. This study therefore assessed a qualitative study on the influence of gender dispositional empathy on mathematics engagement among Atiwa SHS students.

1.1 Objective of the Study

The main aim of the study was to investigate the influence of cognitive dispositional empathy on mathematical engagement of Techiman North Senior High School (SHS) Students. The specific objectives of the study were to:

1. To investigate whether cognitive dispositional empathy affect Techiman North SHS students' mathematical engagement and
2. To find the extent to which students' cognitive dispositional empathy affect their academic performance.

2. Literature Review

Cognition refers to all activity, processes, and products of the mind. Pioneering role by early psychologist addressed important issues in cognitive development of an individual: stage-like versus continuous development, Nature and nurture related issues as well as domain general domain specific Piaget, (1920). Jean Piaget's cognitive theory on child's developmental stages remain the standard against which all other theories are judged, often labeled constructivist because it depicts individuals as constructing knowledge for oneself. Empathy has many different definitions that encompass a broad range of emotional states, including caring for other people and having a desire to help them; experiencing emotions that match another person's emotions; discerning what another person is thinking or feeling; and making less distinct the differences between the self and the other, Owusu-Darko (2016). Empathy necessarily has a "more or less" quality. The paradigm case of an empathic interaction, however, involves a person communicating an accurate recognition of the significance of another person's ongoing intentional actions, associated emotional states, and personal characteristics in a manner that the recognized person can tolerate. Recognitions that are both accurate and tolerable are central features of empathy, Darling Hammond, (2000)

The genetic personality of the individual student assumes the ability to recognize mathematical construct, symbols, generalizations and mathematical concepts (primary or secondary), that can be related to students' mathematical engagement and their performance dispositions, Skemp, (1972).

The Swiss biologist and psychologist Jean Piaget, in his book, '*the origin of intelligent*, Piaget, (1952), Volume 8 no.5 pp18 observed his children (and their process of making sense of the world around them) and eventually developed a four-staged model of how the mind process new information encountered. These four stages are the sensorimotor (birth - 2 years), preoperational (2-4years), the concrete operational (ages 7-11 years) and formal operations (11 years and above) respectively have their respective mental cognition of exhibiting a change behavior when put in the forefront of teaching and learning (of mathematics). The Ghanaian system of SHS education places the student at the last stage of Piaget's developmental stages and can now think abstractly in a more formal way. The cognitive constructivism at stage over mathematical concept formation when engaged in mathematical activities could a dimensional survey in terms of linkage to academic dispositional empathy compared with individual achievement to other subjects.

Empathy is distinct from sympathy, pity, and emotional contagion. Sympathy or empathic concern is the feeling of compassion or concern for another, the wish to see them better off or happier. Pity is a feeling that another is in trouble and in need of help as they cannot fix their problems themselves, often described as "feeling sorry" for someone. Emotional contagion is when a person (especially an infant or a member of a mob) imitatively "the emotions that others are showing without necessarily recognizing this is happening, (Darling Hammond, 2000; Gordon, 1999 Owusu-Darko, 2016).

An empathic disposition has been seen as a desirable trait for teachers in diverse settings. This disposition has been identified as key characteristics in being effective in urban diverse schools (Darling Hammond, 2000; Gordon, 1999). Situation of such is not different from Techiman North District of Ghana were cognition of students in mathematics engagement and performance is perceived in different dimension, whether good or bad, interpreted differently by all stakeholders of the school stream.

This cognitive empathic disposition often manifests itself in students' caring relationships with mathematics engagement. Researchers have noted that students, especially students of color, who have caring relationships with their teachers, are more motivated and perform better academically than students who do not (Foster, 1995; Gay, 2000; Irvine, 1990). In addition, empathy can potentially foster openness, attentiveness, and positive relationships. In culturally diverse classrooms, being open and flexible helps teachers adjust to varying contexts (Delpit, 1995). How often do mathematics educators consider cognition and metacognition level of students when engaging them in mathematics? Teachers are better able to modify pedagogy and curricula to fit their students' needs. The teacher who changed a classroom ritual to be more comfortable for her maturity level to adjust to mathematical metacognition might be considered as a hero. The effect of student's cognitive dispositional status can one way or the other play enormous role in mathematical engagement irrespective of the teacher's methodological and pedagogical move set in the classroom. The human mind is much more complex than simple cognitive abilities and processes and their presentations, (Demetriou & Kazi, 2001). Demetriou et al. (2005) suggest that both the working memory and the processing efficiency are associated with individual development differences on thinking, as cited by Panaoura, (2006).

Panaoura, (2006) realized that there is a very close relation between the development of mathematical performance, the development of metacognition and the development of processing efficiency and working memory. The implication of this finding is very clear: the complexity and the constructions in mathematics at a particular age reflect to a large extend the available processing and representational resources of the human mind. A similar situation in Techiman North District needs to be investigated along this dimension, but at this time, looking at student's mathematical engagement and corresponding performance dependent or independent of their cognitive dispositional status.

Performance determinants have been a periodic theme throughout the literature in educational academic studies in general and in mathematics studies in particular. Mathematics is often considered to be a domain in which it is influenced by gender, age related variables, geographical Location or even formal school attended as well as students attitudes and self-concept developed towards the study of mathematics, (Owusu-Darko, N. Frimpong & I. K. Adu, 2014)

2.1 Cognition versus Mathematics Performance

The cognitive structure of students to adjust to mathematical engagement and hence, perform well has been the concern of most authors, (Panaoura et al, 2006; Finn et al, 2014, Owusu-Darko, 2016)

The emphasis of the Panaoura et al study is on the impact of the development of processing efficiency and working memory ability on the development of metacognitive abilities and mathematical performance. The study had administered instruments measuring pupils΄ metacognitive ability, mathematical performance, working memory and processing efficiency to 126 pupils (8-11 years old) three times, with breaks of 3-4 months between them. Results indicated that, processing efficiency had a coordinator role on the growth of mathematical performance, while self-image, as a specific metacognitive ability, depended mainly on the previous working memory ability', Pandora, (2006). Memory building and recognition of mathematical concept is best notice if the student adjusts well to mathematics engagement through different mathematical engagement.

In the bid to model relationship between cognitive skills and mathematics performance, Finn et al looked at 'Cognitive skills predict academic performance', so schools that improve academic performance might also improve cognitive skills. To investigate the impact schools have on both academic performance and cognitive skills, the study related standardized achievement test scores to measures of cognitive skills in a large sample (N=1,367) of 8th-grade students attending traditional, exam, and charter public schools. Test scores and gains in test scores over time correlated with measures of cognitive skills. There is the need to model a similar relation to mathematical cognition to mathematical engagement in Techiman North District.

A Study of Learning Mathematics Related to some Cognitive Factors and to Attitudes conducted by Dalal Farahan Alenezi look capacity and it dependency on mathematics performance. The study investigated the influence of working memory capacity and field dependency on mathematics achievement. The working memory space and the degree of field dependency were measured for 1346 school students aged between 14-16 years from public schools in Kuwait. In order to investigate the correlations between performances in different topics in mathematics and the working memory space and field dependency, mathematics tests were developed where some questions had high working memory demand and others had very low working memory demand. The results indicated that field dependent students with low working memory capacity perform badly in mathematics, Dalal F. A. (2008).

The great Intuitionist mathematician philosopher L. E. J. Brouwer (1869), identified mathematics with certain mental phenomena and defined Mathematics as "*the mental activity which consists in carrying out constructs one after the other*". This could be perceived as difficult or otherwise per cognition of the mathematical content and adjustment of to the mathematical engagement developed through pedagogical development.

3. Method and Materials

The study used a cross sectional source of data with a sample size of 156 respondents across the students randomly selected from the three SHS in Techiman North District of Ghana namely, Techiman SHS, Akumfi-Ameyaw SHS and Tuobodom SHS. The study adopted both descriptive and qualitative methods in analyzing the data. A random sampling method was used to solicit for information about the respondents in the study area per their mathematical engagement relative to their cognition in Mathematics lessons. The study used questionnaires and interviews to retrieve all the relevant information needed for the study. The study used both SPSS and STATA software's in the processing and the interpretation of the data gathered from the field. A Pearson chi-square test of independence and Crammer's V test were used for the analyses

3.1 Conceptual Framework of Pearson Chi-Square and Crammer's V

The chi-square statistic is a sum of terms each of which is a quotient obtained by dividing the square of the difference between the observed and theoretical values of a quantity by the theoretical value defined along the magnitude of categorical counts (qualitative response variables), Owusu-Darko, (2016).

In general, the hypothesis of independence between two variables in which one is classified into r classes and the other into c classes gives an $r \times c$ contingency table or r, mutually exclusive cells, where r is the number of rows and c the number of columns. That is, one variables contingent (or dependent) on the other. Table 1 is an $r \times c$ contingency table in which variable 1 is classified into r classes and variable 2 into c classes.

Table 1: A $r \times c$ contingency table

Variable 1	**1**	**2**	$\cdots$	**c**	**Totals**
1	0_{11}	0_{12}	$\cdots$	0_{1c}	R_1
2	0_{21}	0_{22}	$\cdots$	0_{2c}	R_2
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
r	0_{r1}	$\cdots$	$\cdots$	0_{rc}	R_c
Totals	C_1	C_2	$\cdots$	C_c	n

The observation in each cell is called the **observed cell frequency** representing number of categories defined by total number of respondent in respective nominal study variables.

$R_i = \sum_{j=1}^{c} o_{ij}$is the marginal total for row i, whilst
$C_j = \sum_{i=j}^{r} o_{ij}$is the marginal for column j.
Where $\sum_{i=1}^{r} R_i = \sum_{j=1}^{c} C_j = n$ is the total sample size.

We can test the null hypothesis:
H_0: *variables are independent against the alternative*
H_1: *variables are not independent*
The test statistic (Pearson independent chi-square estimator) is given by

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(o_{ij} - e_{ij}\right)^2}{e_{ij}}, \qquad (4.1)$$

Where e_{ij} is the expected cell frequency for the (ij)th cell. It can be shown that

$$e_{ij} = \frac{R_i \times C_j}{n}$$

The statistic in Equation (4.1) under the null hypothesis has an approximate chi-square distribution with the number of degrees of freedom given by $(r - 1)(c - 1)$.The critical region for the test at α% significance level is therefore,

$$\chi^2 \geq {\chi^2}_a[(r-1)(c-1)]$$

In tests for independence, both row and column marginal totals are free to vary although the sample size is fixed. The test for independence or homogeneity is a test of association under consideration.

After we have performed a chi-square test of independence and found the two variables to be dependent, we may want to measure the strength of dependence between the two variables. This may be done by finding a constant c called the contingency coefficient. It is given by:

$$c = \sqrt{\frac{\chi^2}{n + \chi^2}}$$

Where

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(o_{ij} - eij)}{eij}$$

and n is the sample size. The coefficient, c, is always approximately 0 when the two variables are independent. A disadvantage associated with is that its value is always less than 1, even when the two variables are completely dependent on each other. For this reason, Cramer's V, given by:

$$V = \sqrt{\frac{\chi^2}{nt}}$$

Where t is the smallest of the two numbers (r–1) and (c–1), is preferred. The value of V lies in the internal from 0 to 1.

The study adopted a descriptive response where necessary and observable variables X_i expressed as percentages

$$\frac{X_i}{\sum_{i=1}^{n} F_i} \times 100 = \varphi\%$$

Of students' response on categorical variables defined for study variables of students' response.

4. Empirical Results

4.1 Descriptive Analysis

This sub-section discusses the nature of relationship existing between students' response variable on cognitive dispositional status and their mathematics engagement in Techiman North SHS. The analyses further elaborates on the dependency of students' Academic Performance (AP) on students' cognition disposition on their AP.

4.2 Students Cognitive Empathy on Mathematical Content

The study's analyses investigated into students' cognitive empathy on mathematical content in Techiman North SHS, a focus on the research question *"what is the relationship between Students' cognitive empathy (SCE) and their interest in solving mathematical related problems among Techiman North senior High School"*. Table 2 gives a descriptive response express as percentages, students response whether mathematical contents is difficult to understand cognitively, status of the mind to understand mathematical contents and whether mathematics content helps develop students mind and teaches a person to think.

Table 2: Mathematical content is difficult to understand cognitively

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	22	27.8	13.7	27.8
	Disagree	28	29.1	17.7	30.4
	Agree	46	17.7	29.1	59.5
	Strongly Agree	44	13.9	27.8	87.3
	Undecided	18	11.4	11.4	100.0
	Total	158	100.0	100.0	
Your mind goes blank when you are unable to think clearly when working mathematics					
Valid	Strongly Disagree	28	17.7	17.7	17.7
	Disagree	84	53.2	53.2	70.9
	Agree	28	17.7	17.7	88.6
	Strongly Agree	18	11.4	11.4	100.0
	Total	158	100.0	100.0	
Mathematics helps develops the mind and teaches a person to think					
valid	Strongly Disagree	42	26.6	26.6	26.6
	Disagree	38	24.1	24.1	50.6

	Agree	32	20.3	20.3	70.9
	Strongly Agree	32	20.3	20.3	91.1
	Undecided	14	8.9	8.9	100.0
	Total	158	100.0	100.0	
Satisfaction gained in solving mathematical problem					
Valid	Strongly Disagree	26	16.5	16.5	16.5
	Disagree	50	31.6	31.6	48.1
	Agree	14	8.9	8.9	57.0
	Strongly Agree	28	17.7	17.7	74.7
	Undecided	40	25.3	25.3	100.0
	Total	158	100.0	100.0	

From Table 2, a cumulative 30.4% of the respondents disagreed to seeing mathematics content as difficult. On the contrary, about 67.8% agreed to the fact that mathematics is seen intuitively as difficult.

Intuitionist conceptual and philosophical definitions of the nature of mathematics, developing from the philosophy of mathematician L. E. J. Brouwer (1869), identify mathematics with certain mental phenomena. An example of an intuitionist definition is that "*Mathematics is the mental activity which consists in carrying out constructs one after the other*." A peculiarity of intuitionism is that it rejects some mathematical ideas considered valid according to other definitions. In particular, while other philosophies of mathematics allow objects that can be proven to exist even though they cannot be constructed, intuitionism allows only mathematical objects that you can mentally construct.

Mathematics is seen by many and sundry students' as difficult and can have negative cognitive perceptual disposition about the conceptual definition of mathematical contents. From Table 2, much is seen on students' response directed towards the fact that mathematics is difficult, mind goes off when studying it etc.

Table 3: Relationship between Cognitive empathy and Dispositional empathy

		Effect of dispositional empathy on Students Academic Performance							
		Excellent	Very good	Good	Credit	Pass	Fail	Total	Pearson chi-sqr
Mathematical content is difficult to understand cognitively	Str Disagree	0	6	0	16	0	22	44	$\chi^2_{(0.05,20)} = 120.421$
	Disagree	0	0	12	6	16	12	46	$P-value = .0.00$
	Agree	4	4	10	4	6	0	28	

Str Agree	4	6	0	6	6	0	22
Undecided	0	0	0	12	6	0	18

Source: field survey (2016)-Results are based on nonempty rows and columns in each innermost sub-table. *. The Chi-square statistic is significant at the 0.05 level

Table 3 gives a 5 by 6 contingency Pearson chi-square independence test between whether mathematical content is difficult to students and their dispositional empathy on Academic performance. Independent variable on students' response are based on whether they strongly disagree, disagree, agree, strongly agree or undecided about the assertion under discussion. Students Dispositional Empathy on Academic Performance is categorized on grade interpretation-Excellent, Very good, good, credit, pass or fail based on Ghana Education Service (GES) criterion grade interpretation for Senior High Schools.

The study sought to test the hypothesis that

H_0: *Dispositional empathy on student Academic Performance (AP) is independent of students' response on whether Mathematics content is difficult.*

Against

H_1: *Dispositional empathy on student Academic Performance (AP) is independent of students' response on whether Mathematics content is difficult.*

At a significance level of $\alpha = 0.05$, a decision precision level of

$$100(1-\alpha)\% \cong 95\%$$

A Pearson independent chi square is computed using an SPSS output estimator as

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(o_{ij} - e_{ij}\right)^2}{e_{ij}} = 120.421$$

That is

$$\chi^2 = 120.421$$

with the number of degrees of freedom given by

$$(r-1)(c-1) = (5-1)(6-1) = 4 \times 5 = 20\ d.f.$$

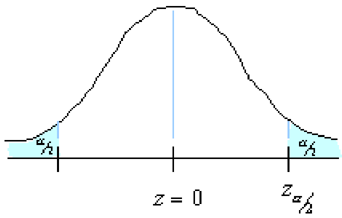
The critical region for the test at $\alpha\% = 5\%$ significance level is the probability of rejecting the H_0. Hence the computed chi-square at 20 d.f is given as

$$\chi^2_{[(r-1)(c-1)]} = \chi^2_{(0.05,\ 5)} = 120.421$$

The study realized a significance chi-square test at $\alpha = (0.01), (0.05) and (0.1)$ respectively since SPSS calculated

$$P - value\ of\ 0.00 < (\alpha = 0.05).$$

We fail to reject H_0, hence it is statistically significant. We have insufficient evidence to reject H_0.



$$\chi^2_{(0.05,\ 5)=34.72}$$

It is concluded here however that, Dispositional empathy on student Academic Performance (AP) is independent of students' response on cognitive dispositional empathy. Again, the fact that a student see mathematics as difficult to understand cognitively or not doesn't mean he or she can't pass mathematics evaluated lesson. That is, a student noticing mathematics as intuitively difficult or easy doesn't guarantee passing with excellent, very good, good, credit, pass or fail etc.

The graph below is a pictorial representation of the relationship between students response on the nature of mathematics content and students' dispositional grades usually obtained in each term.

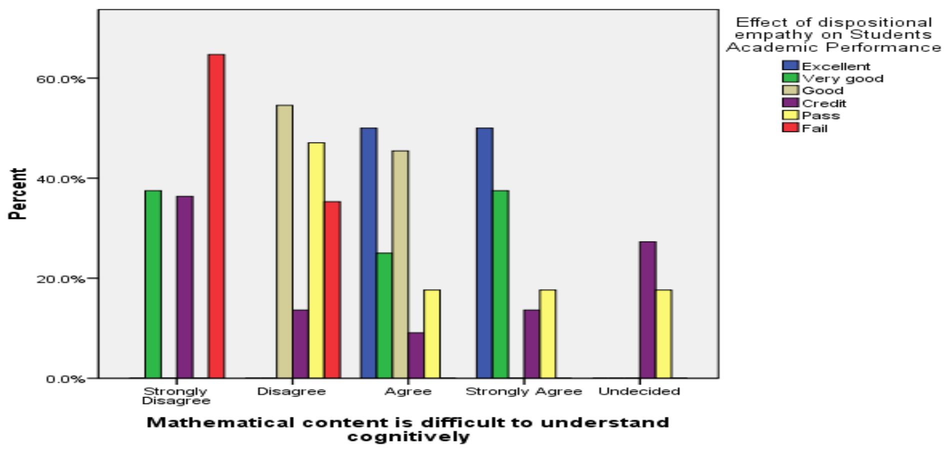


Figure 1: A multiple bar graph showing students response on Nature of mathematical content and DE

Figure 2: A multiple bar graph showing students response on Nature of mathematical content and dispositional empathy.

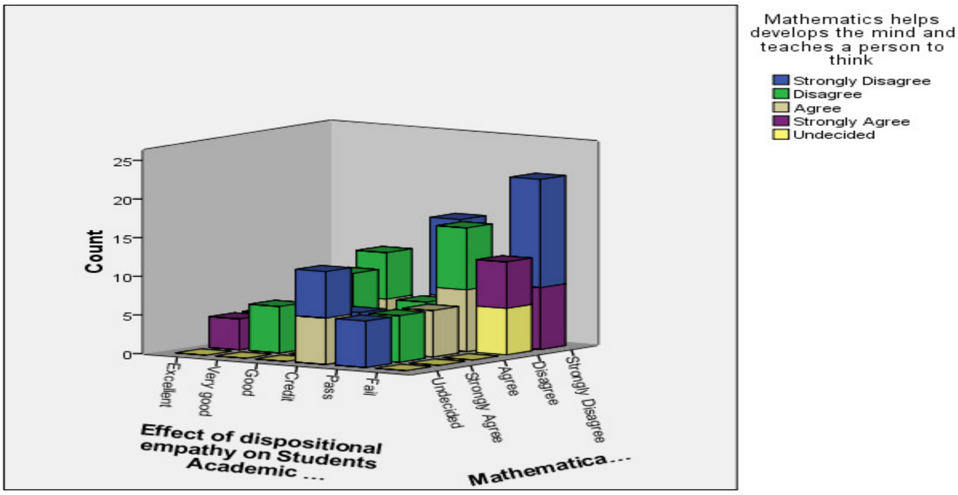


Figure 2: A 3-D bar chart on decision about Mathematical content clustered within SDE

Figure 2 showing a 3-D bar chart on decision about Mathematical content clustered within SDE.

Both figure 1 and 2 reveals effect of SDE on AP with majority of respondents disagreeing along Fail to credit pass zones.

5. Conclusions

The study analyzed students' response on Students cognitive empathy (SCE) and their mathematical engagement and corresponding academic performance. A cumulative 30.4% of the respondents disagreed to seeing mathematics content as difficult. On the contrary, about 67.8% agreed to the fact that mathematics is seen intuitively as difficult as it is seen. The study sought to test the hypothesis that, 'dispositional empathy on student Academic Performance (AP) is independent of students' response on whether Mathematics content is difficult at a significance level of $\alpha = 0.05$, a decision precision level of $100(1-\alpha)\% \cong 95\%$. A Pearson chi square estimate of ${\chi^2}_{(0.05,\ 5)} = 120.421$ is tested to be significant at 1%, 5% and 10% respectively. Mathematics is seen by many and sundry students' as difficult and can have negative cognitive perceptual disposition about the conceptual definition of mathematical contents.

It is concluded here however that, Dispositional empathy on student Academic Performance (AP) is independent of students' response on their cognitive dispositional empathy. Again, the fact that a student see mathematics as difficult to understand cognitively or not doesn't mean he or she can't pass mathematics evaluated lesson. That is, a student noticing mathematics as intuitively difficult or easy doesn't guarantee passing with excellent, very good, good, credit, pass or fail etc. The study realized a significance chi-square test at $\alpha = (0.01), (0.05) and (0.1)$ respectively. This is consistent to intuitionist conceptual and philosophical definitions of the nature of mathematics, developing from the philosophy of mathematician L. E. J. Brouwer (1869), identifying mathematics with certain mental phenomena. An example of an intuitionist definition is that "*Mathematics is the mental activity which consists in carrying out constructs one after the other*". This could be perceived as difficult or otherwise per cognition.

6. Recommendations

After careful analyses of the study variables, we recommend the following to GES, the SHS school administration, parent, teachers, students and future researchers where applicable.

1. Students and teachers should not have a generalized outlook on cognitive disparities in the teaching and learning of mathematics in order not to disposition students' interest and engagement in mathematical lesson.
2. Teachers should try as much as possible to satisfy students' affective domain when considering lesson objectives, methodology and evaluation of mathematical lessons as suggested by Bloom et al (1957) taxonomy for instructional learning.
3. Students should take their mathematics lessons serious in order to sharping cognitions of mathematical concepts and psychological status desired to meet mathematical lessons.

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